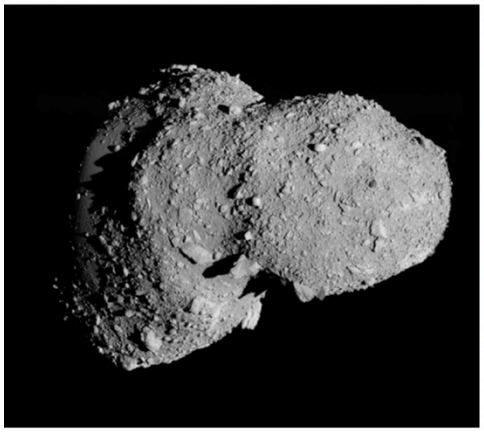
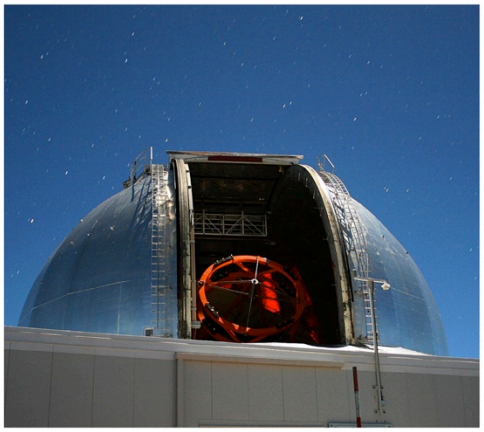
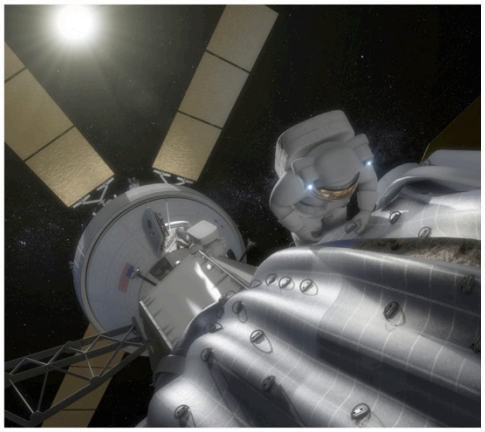
National Aeronautics and Space Administration

NASA NEO Observation Program

Lindley Johnson, NEO Programs Executive

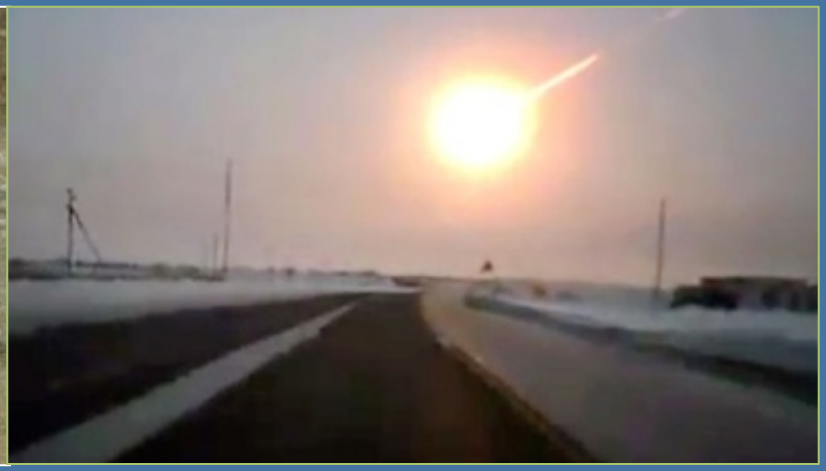
Nov. 20, 2013



Grand Challenge Statement*

Find all asteroid threats to human populations and know what to do about them



*Announced 18 June, 2013

CHELYABINSK EVENT

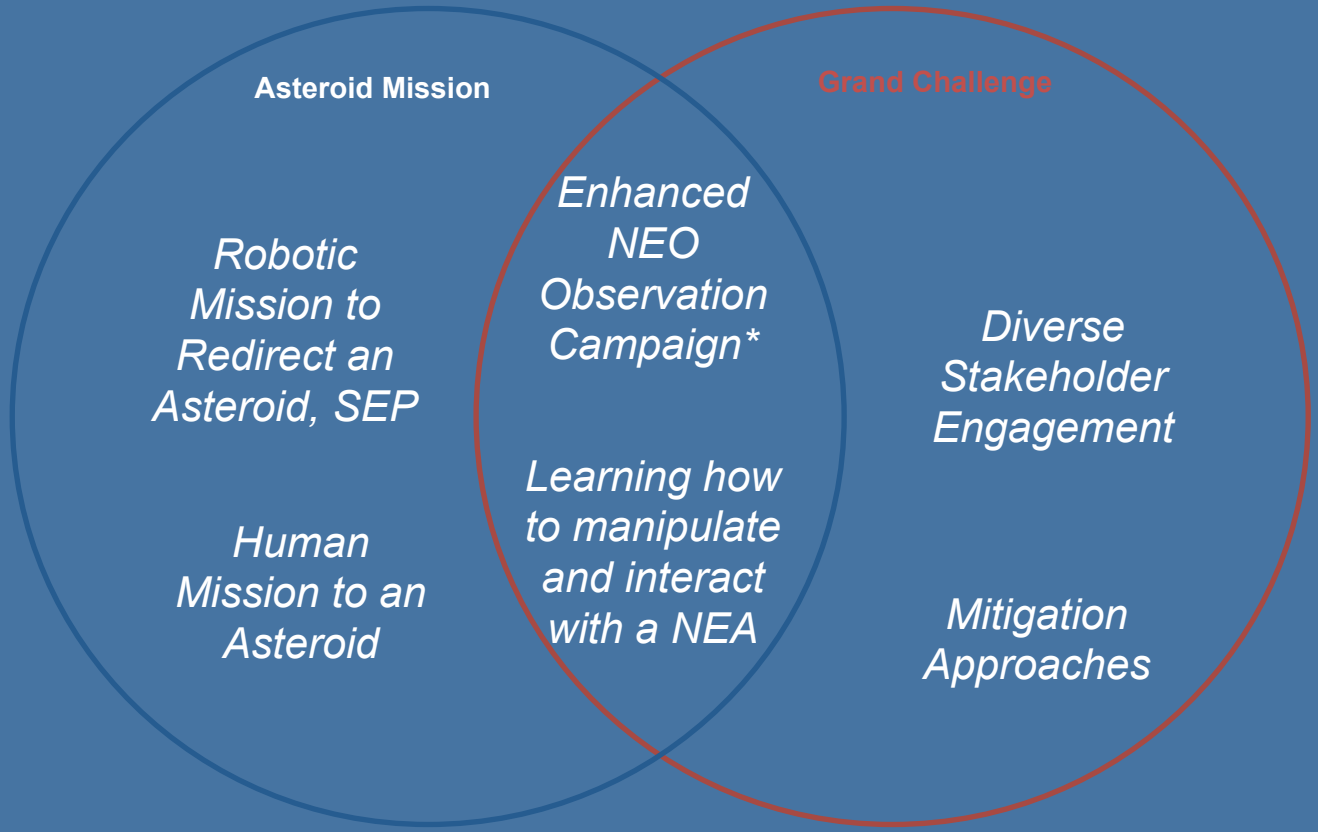
February 15, 2013
17-20 meter object
~500-550 kilotons TNT

CHELYABINSK EVENT

February 15, 2013
1613 citizens injured
~$30 million damages

FY14 Asteroid Initiative: What and How

Asteroid Initiative

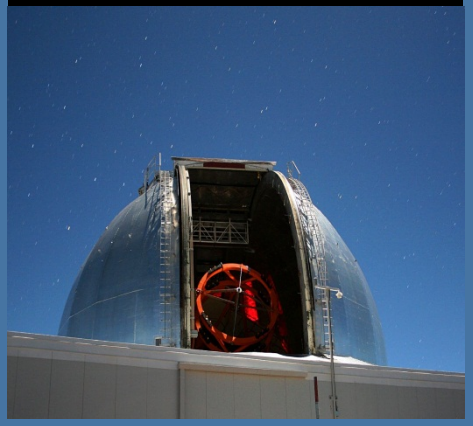


Both sets of activities leverage existing NASA work while amplifying participatory engagement to accomplish their individual objectives and synergize for a greater collective purpose.

* FY2014 PBR increases NEOO Program to $40M

Asteroid Redirect Mission Consists of Three Main Segments

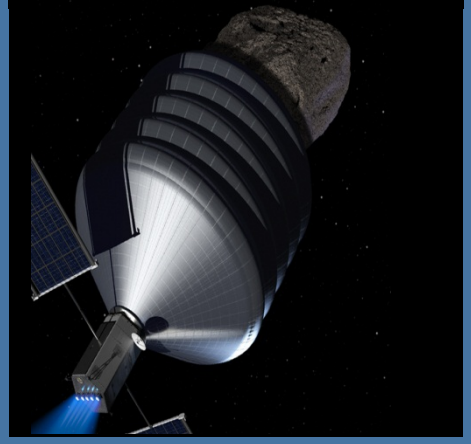
Identify



Asteroid Identification Segment:

Ground and space based NEA target detection, characterization and selection

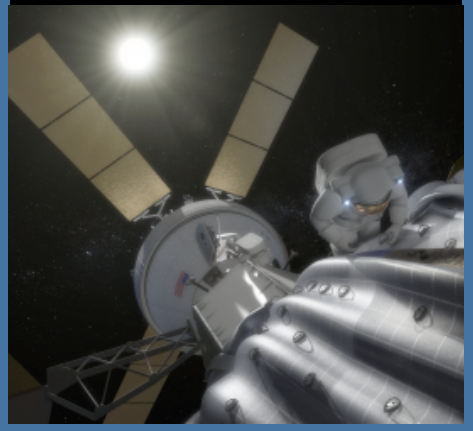
Redirect



Asteroid Robotic Redirection Segment:

Solar electric propulsion (SEP) based robotic asteroid redirect to trans-lunar space

Explore



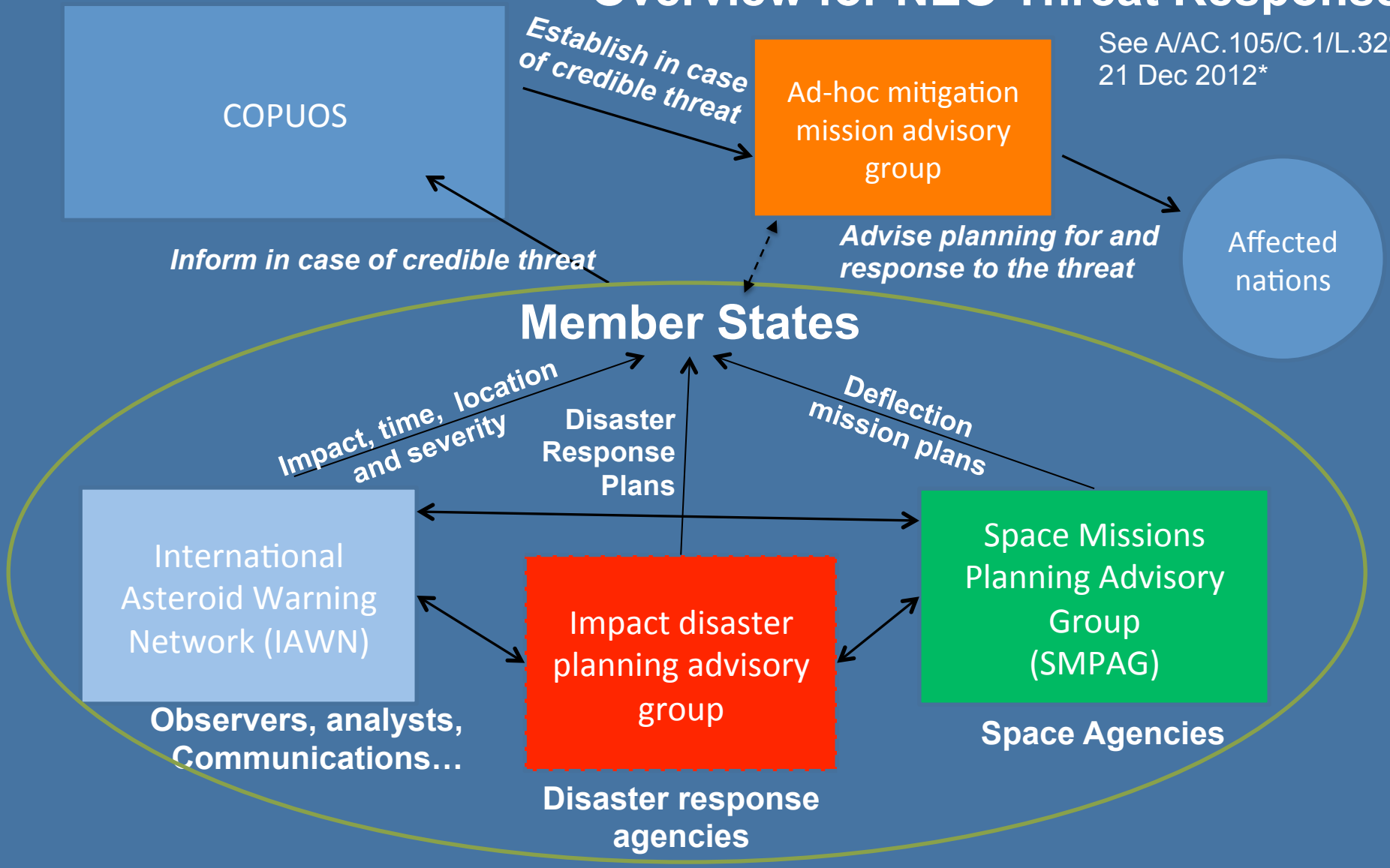
Asteroid Crewed Exploration Segment:

Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid

Tasked to NEOO with additional funding

UN Office of Outer Space Affairs
Committee on Peaceful Uses of Outer Space

Overview for NEO Threat Response



*http://www.oosa.unvienna.org/oosa/en/COPUOS/stsc/wgneo/index.htr

NASA's NEO Observations Program

US component to Spaceguard / International Asteroid Warning Network
Has provided 98% of new detections of NEOs since 1998

Began with NASA commitment to House Committee on Science in May, 1998 to find at least 90% of 1 km and larger NEOs

- Averaged ~$4M/year Research funding 2002-2010
- That goal reached by end of 2010

NASA Authorization Act of 2005 provided additional direction:

"...plan, develop, and implement a Near-Earth Object Survey program to detect, track, catalogue, and characterize the physical characteristics of near-Earth objects equal to or greater than 140 meters in diameter in order to assess the threat of such near-Earth objects to the Earth. It shall be the goal of the Survey program to achieve 90 percent completion of its near-Earth object catalogue within 15 years [by 2020].

Updated Program Objective: Discover ≥ 90% of hazardous NEOs larger than 140 meters in size as soon as possible (2020?)

- Starting with FY2012, now has $20.5 M/year
- Also detects, tracks and characterizes smaller asteroids that approach Earth

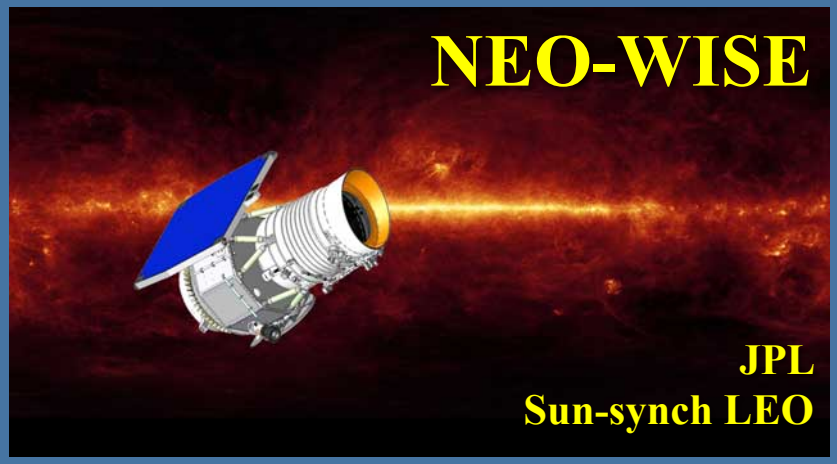
NASA's NEO Observations Program
(Current Systems)

Minor Planet Center (MPC)
- IAU sanctioned
- Int'l observation database
- Initial orbit determination

www.cfa.harvard.edu/iau/mpc.html

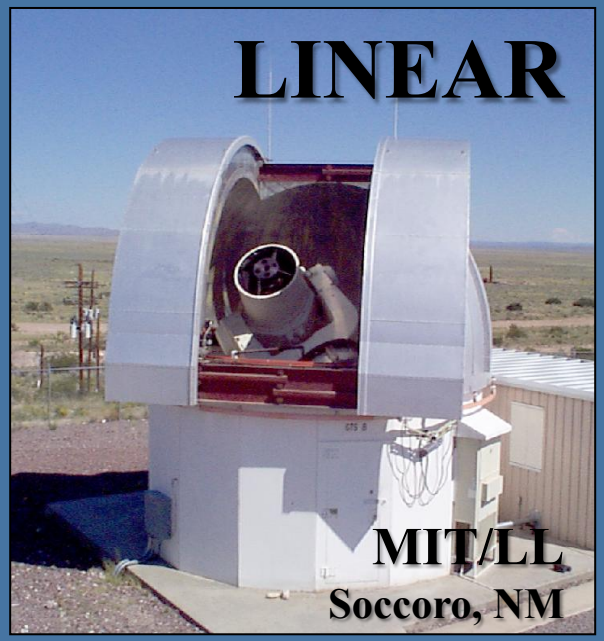
NEO Program Office @ JPL
- Program coordination
- Precision orbit determination
- Automated SENTRY

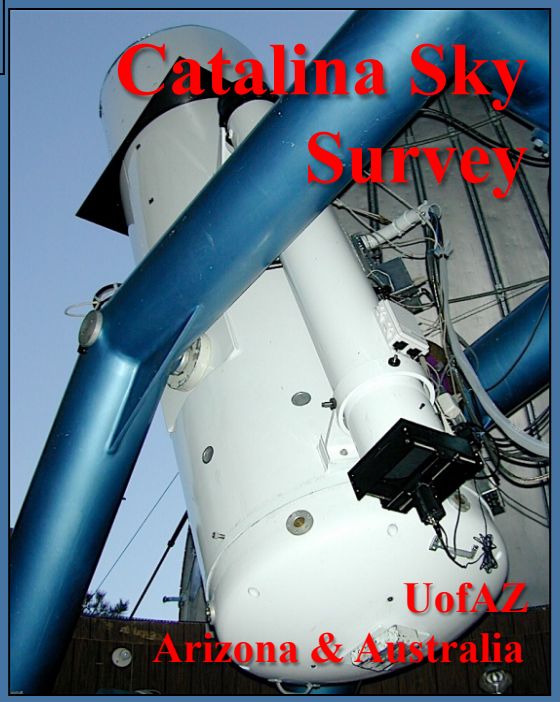
http://neo.jpl.nasa.gov/



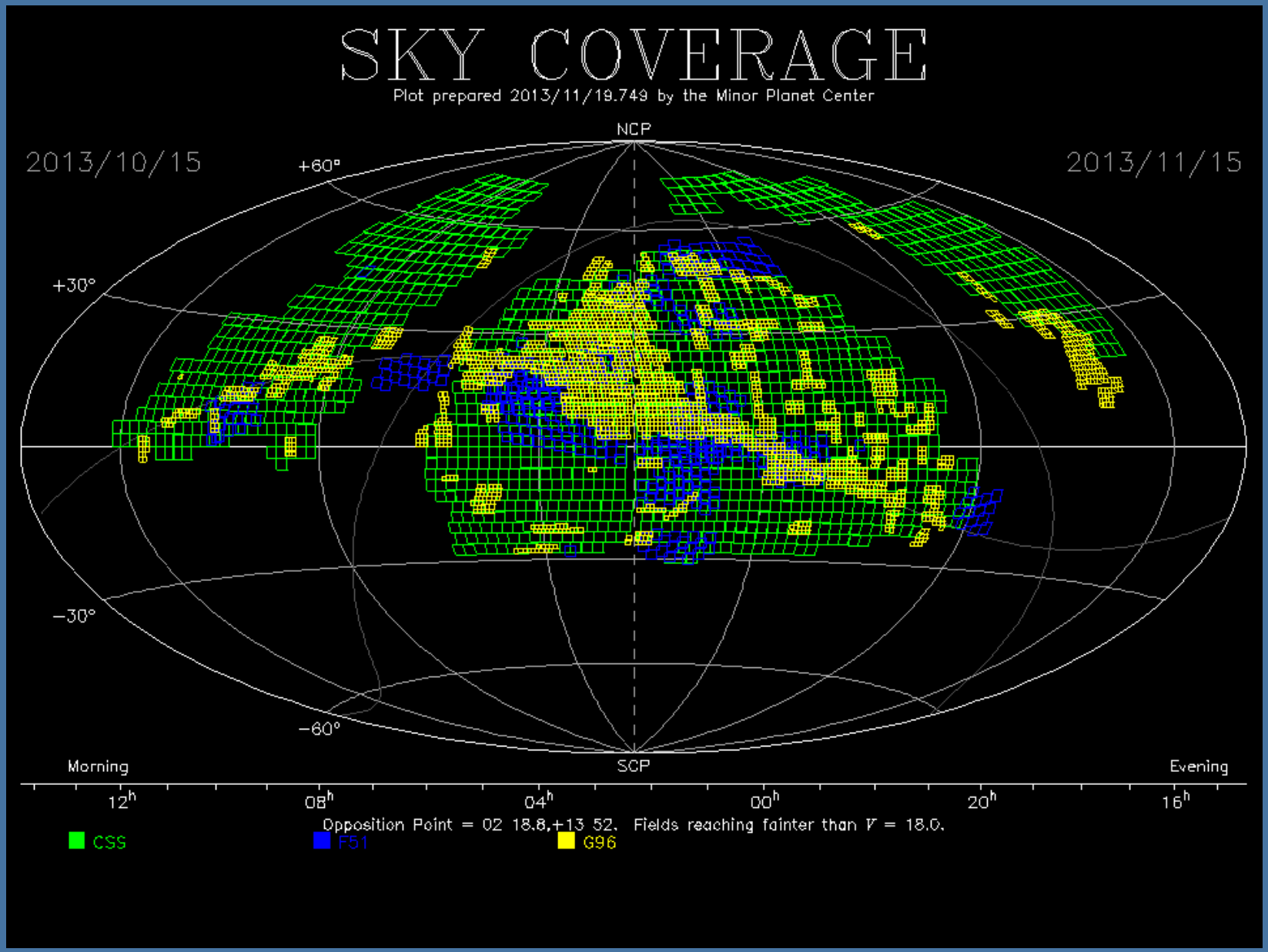
Operations
Jan 2010
Feb 2011,
129 NEAs found

Reactivated
Sep 2013



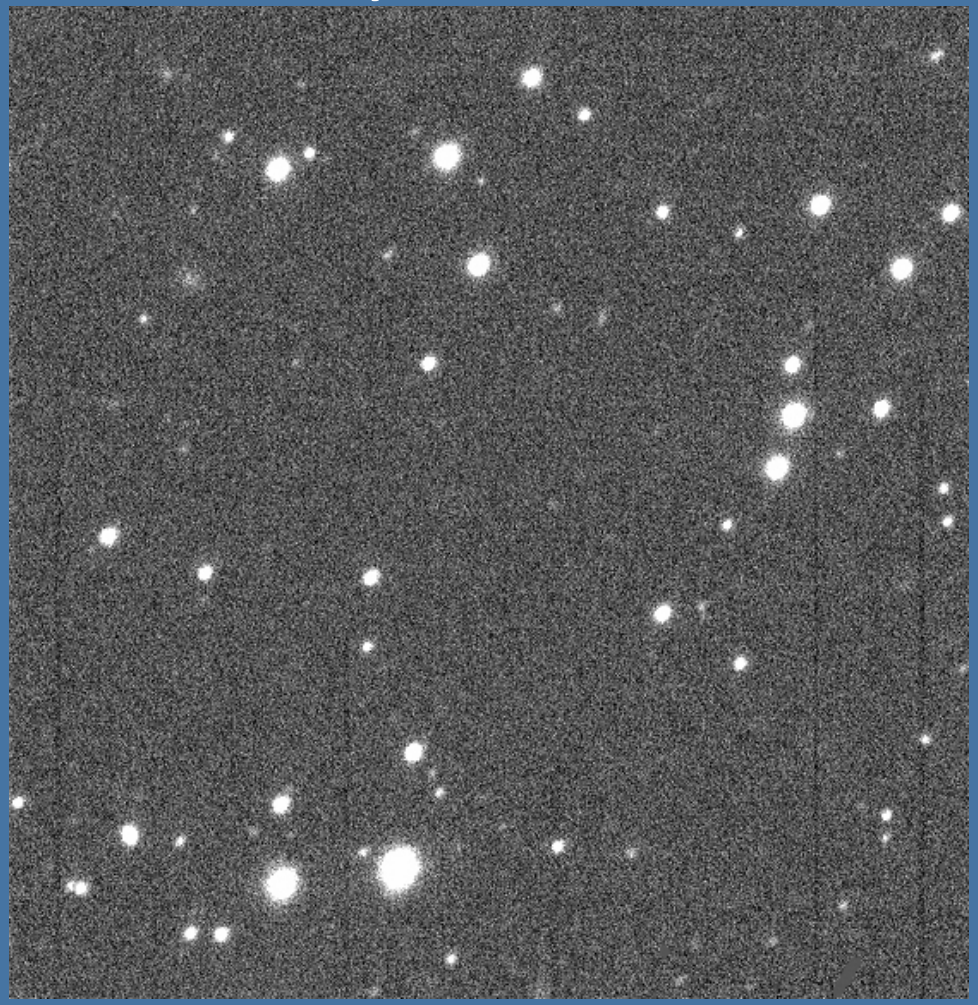


Searching the Sky for Asteroids



Discovery Images of an Asteroid

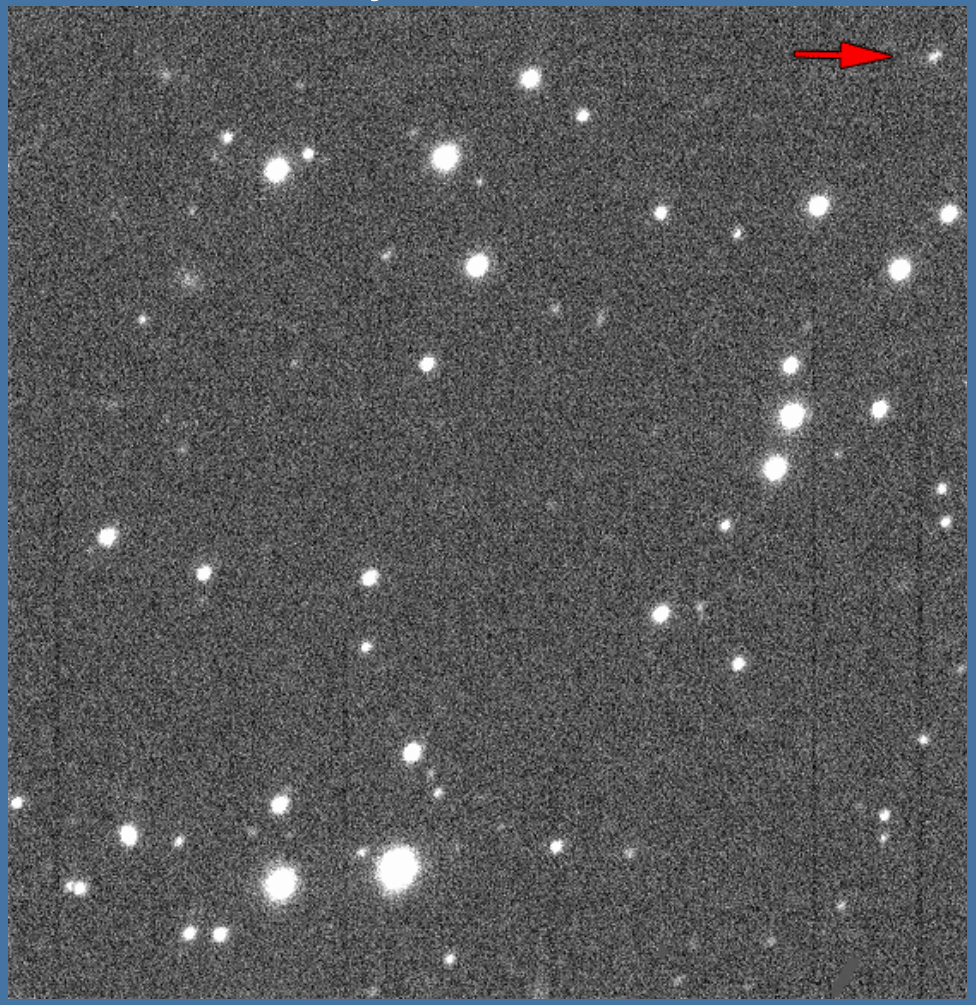
Do you see it?



Courtesy of Pan-STARRS

Discovery Images of Asteroid 2013 MZ5*

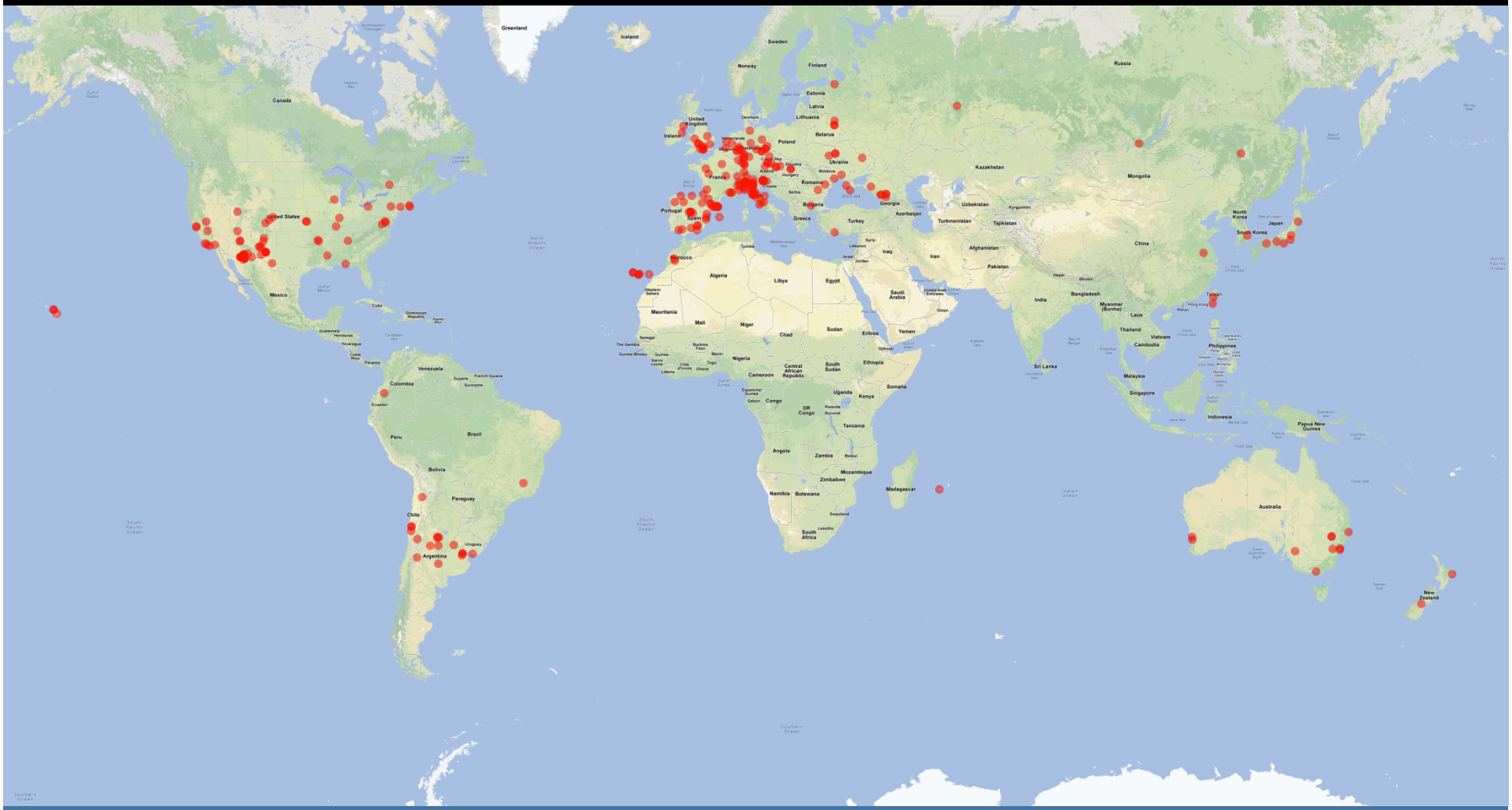
Did you find it?



Courtesy of Pan-STARRS

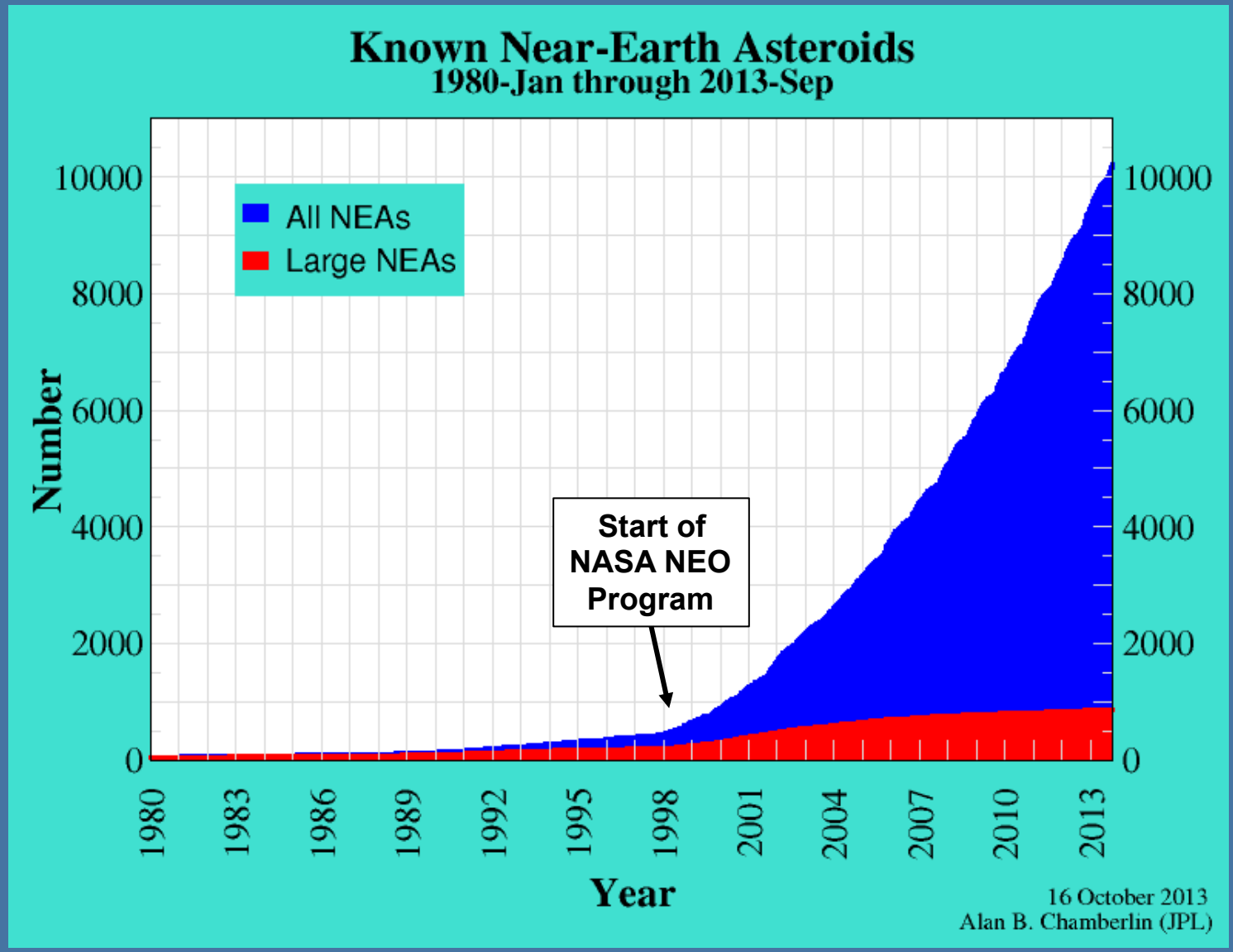
*10,000th NEO Found

Existing Observing Network is Worldwide



Data from 46 countries in 2012

Known Near Earth Asteriod Population

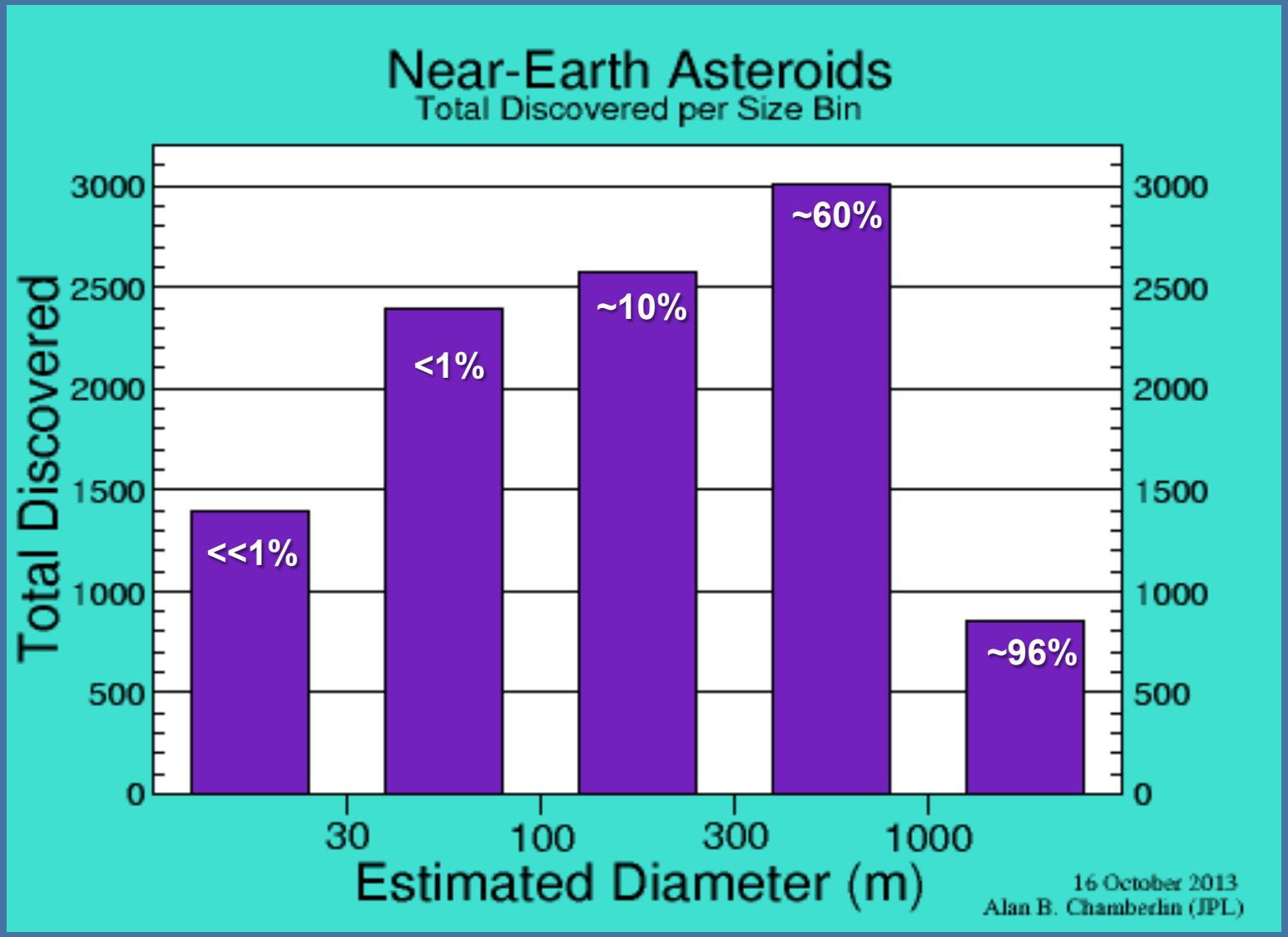


10,450
11/15/13

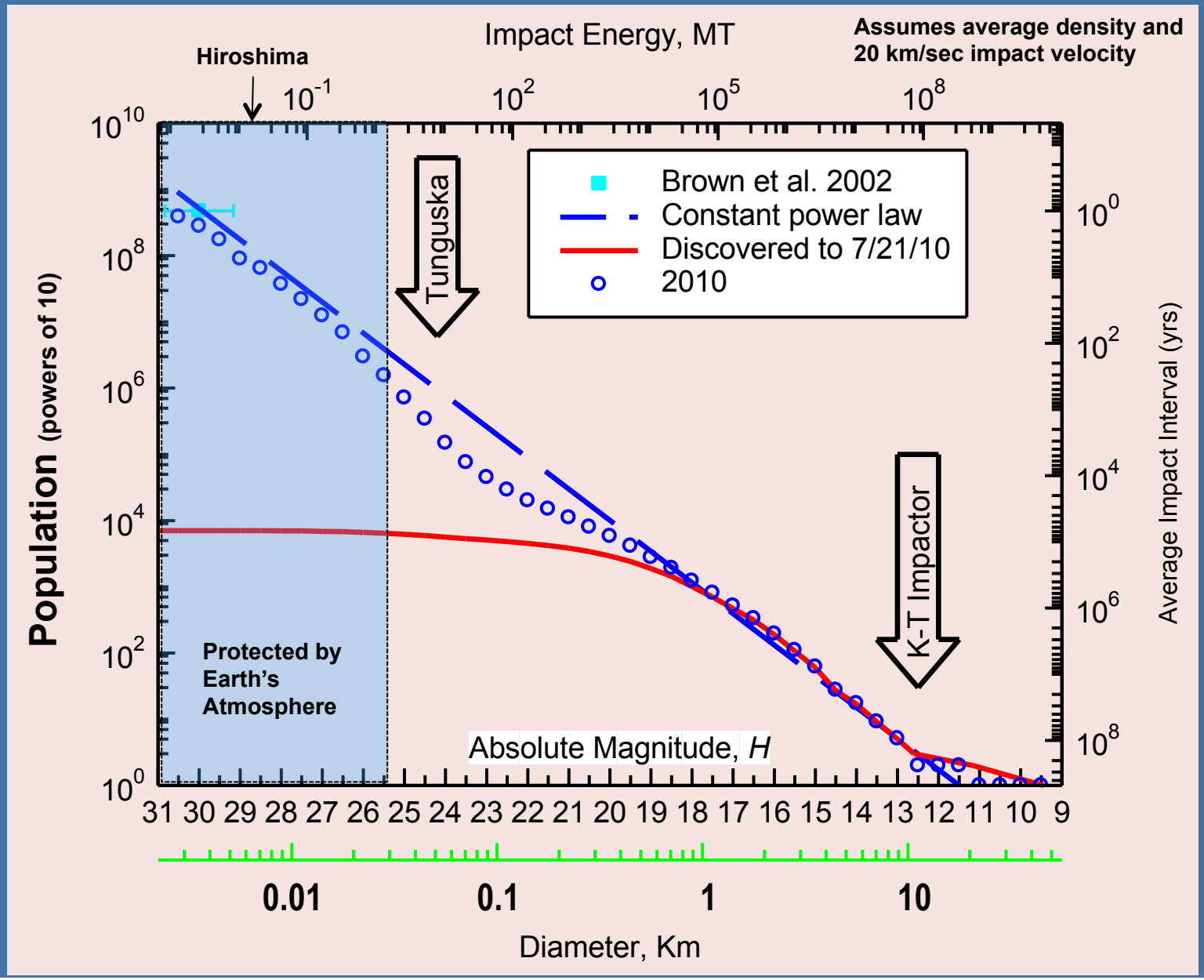
Includes 94 comets

864
11/15/13

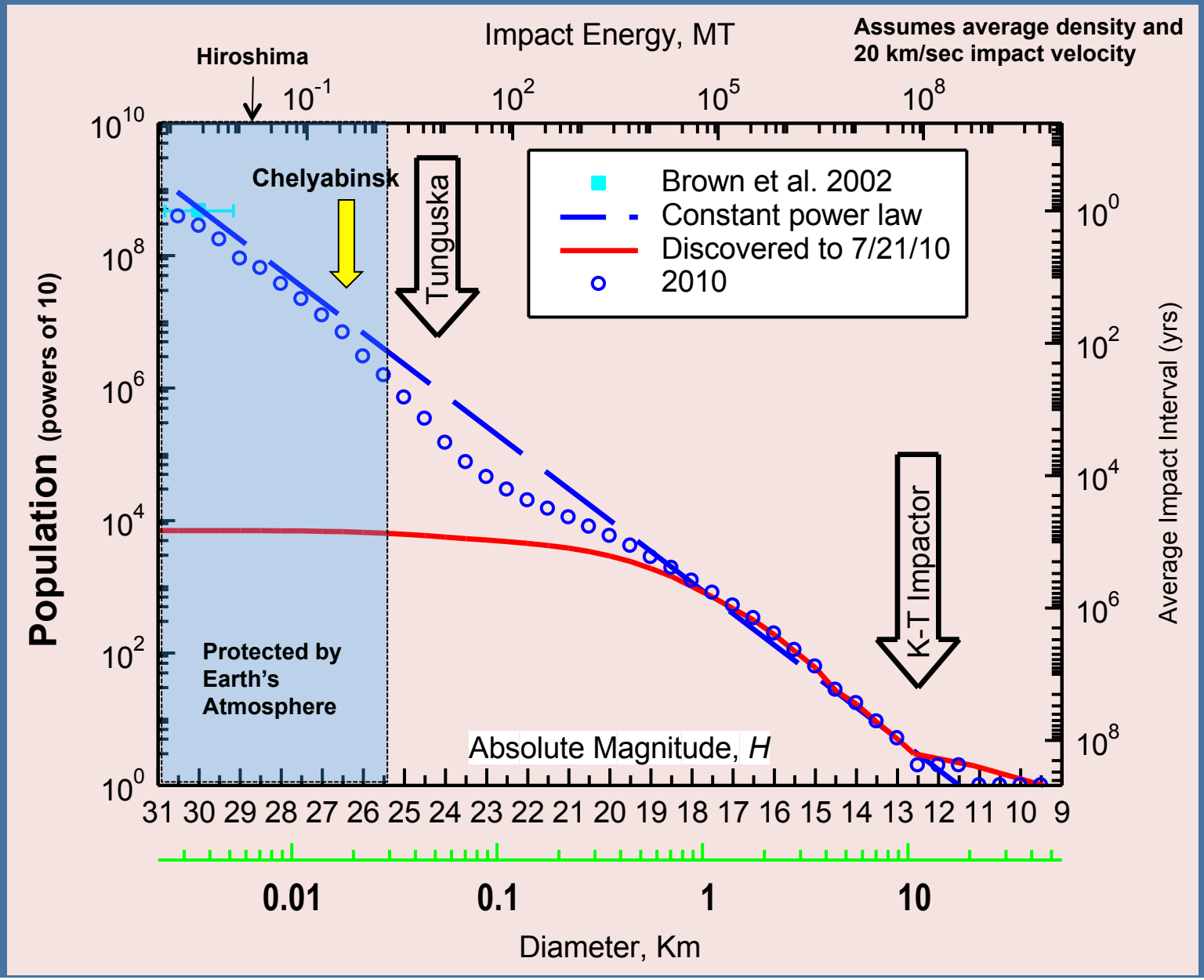
Known Near Earth Asteroid Population



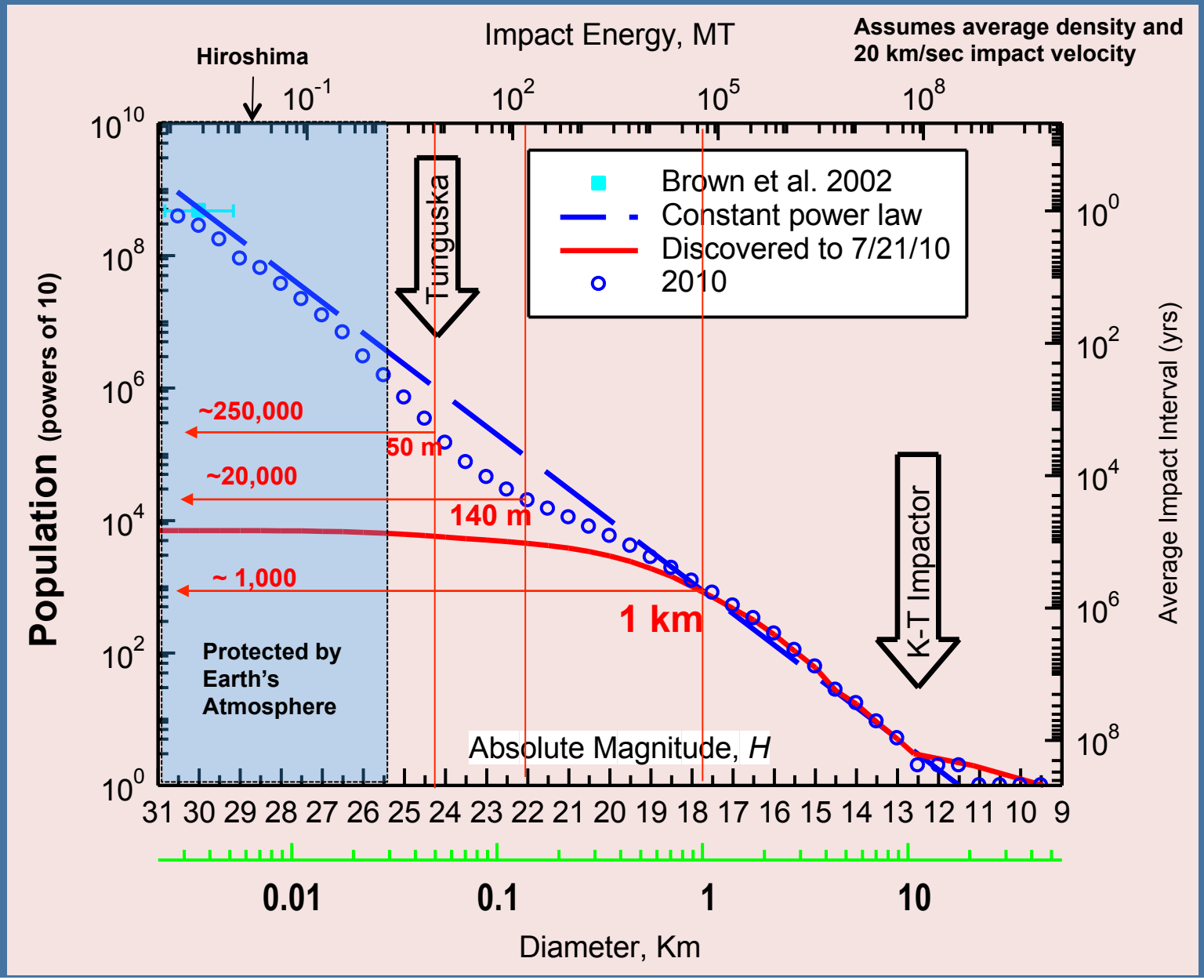
Population of NEAs by Size, Brightness, Impact Energy & Frequency (A. L. Harris 2010)



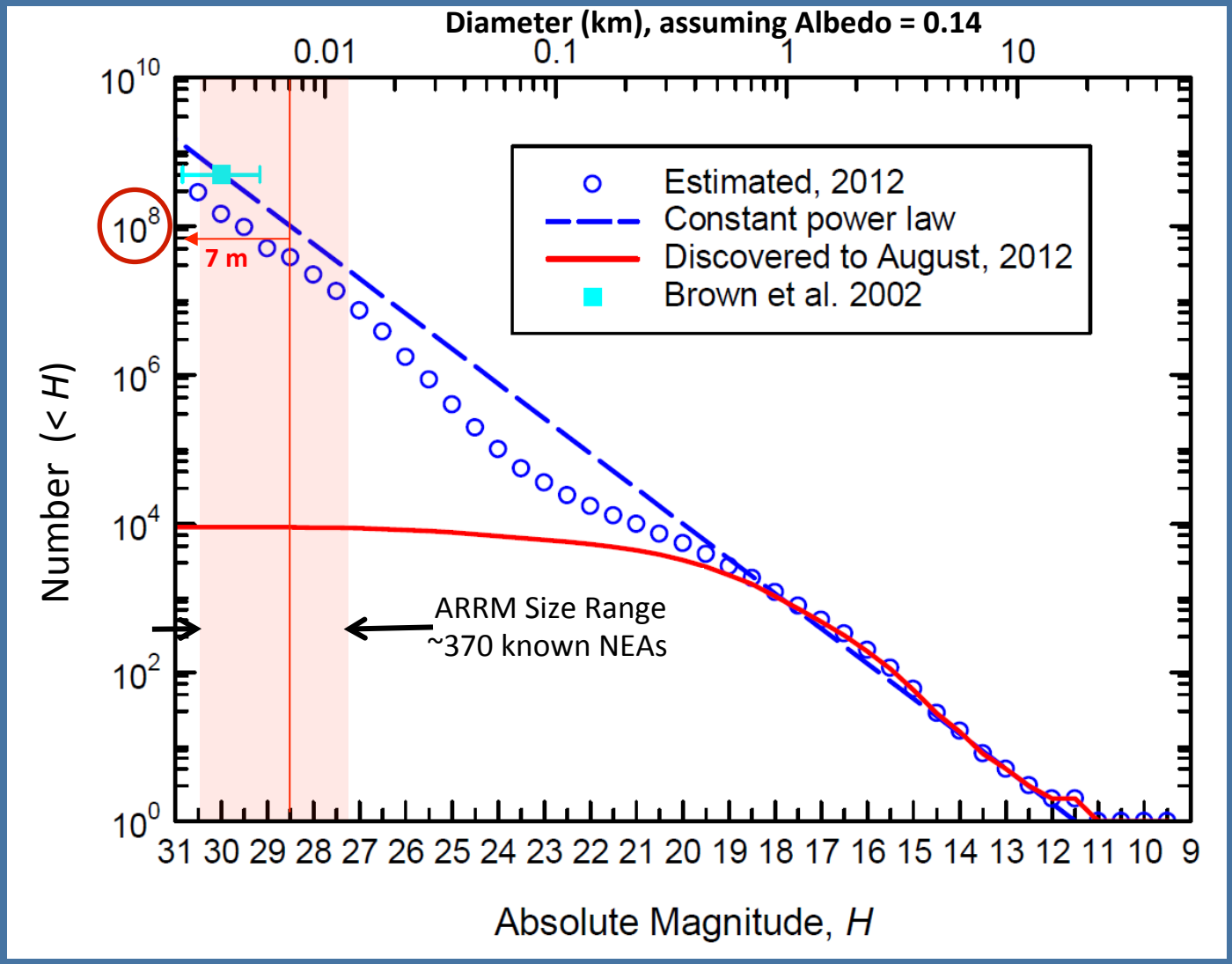
Population of NEAs by Size, Brightness, Impact Energy & Frequency (A. L. Harris 2010)



Population of NEAs by Size, Brightness, Impact Energy & Frequency (A. L. Harris 2010)



NEAs: Total Population vs. Size

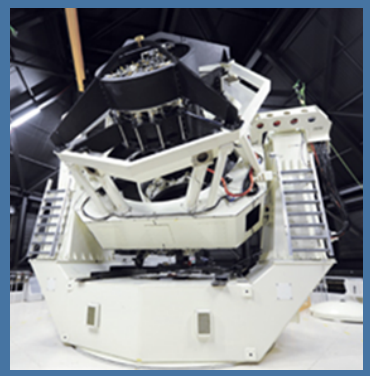


Simulations by Jedicke & Schunova suggest that the total population of suitable ARRM candidates is on the order of 10,000.

Diagram courtesy of Al Harris

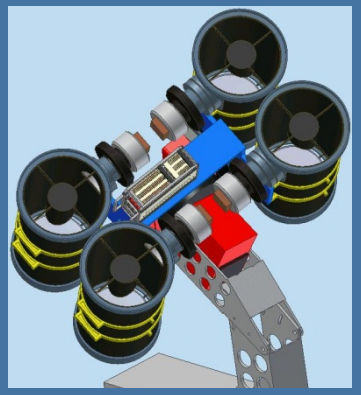
Enhancements for Discovery

- **NEOs on DARPA Space Surveillance Telescope**
  - Built for DoD Space Situational Awareness
  - Testing of NEO detection capability: Fall 2013



- **Enhancing Pan-STARRS 1, Completing Pan-STARRS 2**
  - Increase search time on PS1: Early 2014
  - Complete PS2 (improved copy of PS1): Late 2014

- **Accelerated Completion of new survey ATLAS**
  - Extremely wide field, covering entire night sky every night, but not as deeply. Detects NEAs close to Earth
  - Vendor and working design selected
  - Prototype system sited on Mauna Loa
  - First system completion: Early 2015



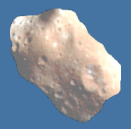
Future Discovery Rate of ARRM Candidates

- The ARRM candidate discovery rate will almost certainly **increase** due to enhancements to existing surveys and new surveys coming online.
- Several asteroid survey enhancements are already in process and funded by the NEOO Program. Some could be accelerated with additional funding.
- A conservative projection, based on study of enhancements, is that the discovery rate will increase to **at least 5 per year**.
- Search for ARRM candidates will continue until final selection.
- With at least another 3-4 years to accumulate discoveries, at least **15 more candidates are expected**.
- With rapid post-discovery characterization capabilities in place, there will be better opportunities to physically characterize future ARRM discoveries.
- Enhancing surveys to find more ARRM candidates also increases their capabilities for finding potentially hazardous asteroids in general.

Physical Characterization of NEAs

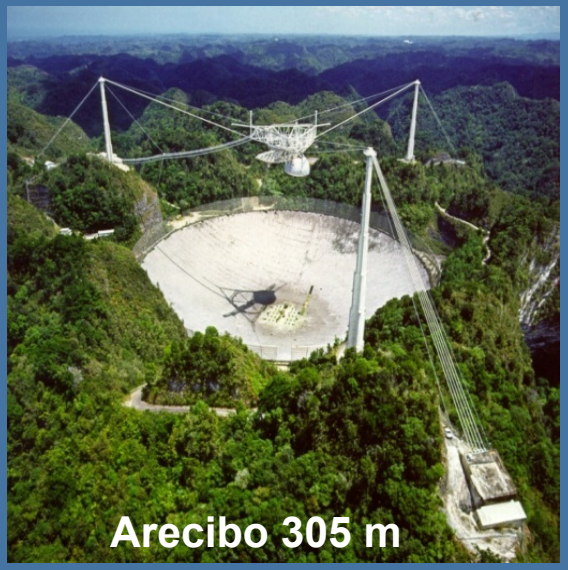
- Even without a characterization mission, it should be possible to set reasonable upper bounds on size and mass.
- **Radar**: size, shape, rotation state, orbit.
- Ground-based and space-based **IR**: albedo and spectral class, and, indirectly, approximate density.
- **Light curves**: shape and rotation state.
- **Long-arc high-precision astrometry**: area-to-mass ratio, orbit. (Gaia catalog promises an order-of-magnitude improvement).
- Mass is estimated from size and shape using an inferred or assumed density, possibly constrained by the the area-to-mass estimate. Mass may only be known to within a factor of 3 or 4.
- Final ARRM target selection may depend largely on how the estimated upper bound on the mass of a candidate compares with the return mass capability for that candidate.

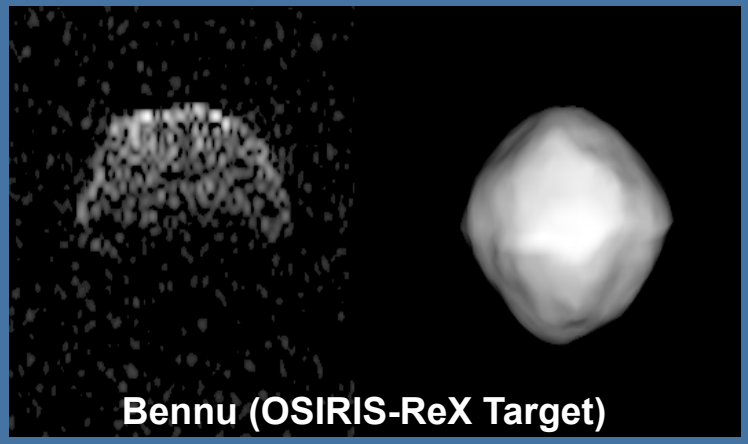
Assumed albedo
ρ = 0.04

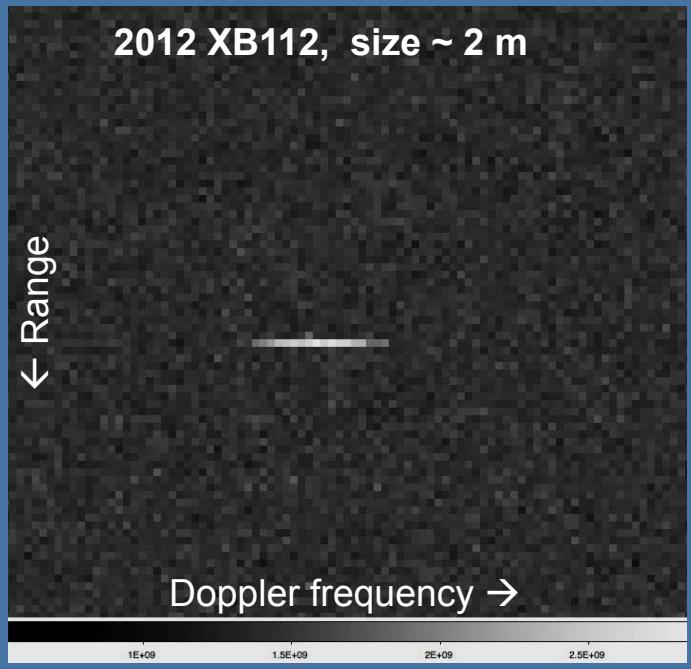


Assumed albedo
ρ = 0.34

Radar Observations of NEAs







- 70-80 NEOs are observed every year.
- 10-m-class NEAs observable out to ~5 lunar distances; ~80% of the ARRM candidates should be radar observable once detected.
- Radar observations can provide:
  - Size and shape to within ~2 meters.
  - High precision orbit data.
  - Spin rate, surface density and roughness.

NEO Characterization Enhancements

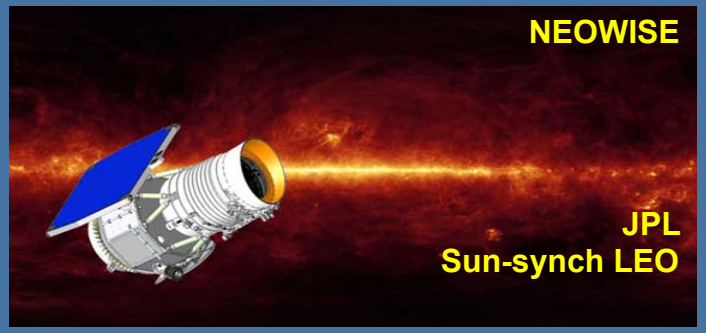
Radar (Goldstone and Arecibo)
- Increase time for NEO observations.
- Streamline Rapid Response capabilities.


Goldstone Radar


Arecibo Observatory

NASA InfraRed Telescope Facility (IRTF)
- Increase On-call for Rapid Response.
- Improve Instrumentation for Spectroscopy and Thermal Signatures.

Reactivate NEOWISE
- ~3 year warm phase dedicated to NEO Search/Characterization data collection.



Summary of NASA NEO Efforts

- NEOO project enhancements will add capability to find hazardous asteroids as well as ARRM candidate targets.
- With several survey enhancements in process, and new surveys coming online within the next 2 years, both the NEO and the ARRM candidate discovery rates should at least double.
- Rapid response after discovery is critical for physical characterization of both hazardous and ARRM candidates. The process has already been successfully exercised for difficult-to-characterize candidates.
- Goldstone and Arecibo radars are key characterization assets for NEAs of interest because they provide accurate estimates of size and rotation state.
- Other major assets for characterization are available. Interchange agreements for target-of-opportunity observing time from important non-NASA facilities (e.g. Keck or Subaru) can be negotiated.
- There are several ongoing efforts with interagency and international entities
- The recent increased interest in NEOs, the hazard and opportunity they pose, has made this a rapidly expanding mission area for Planetary Science.